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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with chemical precipitation softening. Included are objectives, an instructor guide, student handouts and transparency masters. This is the first level of a three module series and is designed for students with little or no operating experience. The module considers the principles, components, operation, maintenance, laboratory control and safety for chemical precipitation softening systems. (Author/RH)

BASIC CHEMICAL PRECIPITATION SOFTENING

Training Module 2.215.2.77

Prepared for the

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by

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September, 1977

TABLE OF CONTENTS

Module No:	Module Title:
II2TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	Topic:
14 hours	Summary

Objectives: Upon completion of this module, the participant will be able to:

1. Describe the chemistry of chemical precipitation softening
2. Describe the operation of chemical precipitation softening
3. Describe the laboratory control necessary for chemical precipitation softening
4. Describe the safety requirements for chemical precipitation softening.

Instructional Aids:

1. Handout
2. Transparencies #1-#22

Instructional Approach:

Discussion and Class Problems

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service
2. Manual of Water Utility Operations, Texas Water Utility Association
3. Water Supply & Treatment, National Lime Association
4. Standard Methods for the Examination of Water and Wastewater, 14th Ed.
5. Methods for Chemical Analysis of Water and Waste, EPA

Class Assignments:

1. The participant will read Handout.
2. The participant will complete Problems #1-#3

Module No:	Topic:
II2TWS	Summary

Instructor Notes:	Instructor Outline:
1. Distribute Handout	1. Discuss and identify the chemistry, operation, laboratory control and safety requirements for chemical precipitation softening.
2. Present Transparencies	2. Give evaluation of 30 questions.

Module No:	Module Title:
II2TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	
	Topic:
	Introduction

Objectives: Upon completion of this topic, the participant will be able to:

1. Describe what hardness is.
2. Describe what chemical precipitation softening is.
3. State advantages of chemical precipitation softening.
4. State disadvantages of chemical precipitation softening.

Instructional Aids:

1. Handout - Introduction
2. Transparency #1 - What is Hardness
3. Transparency #2 - What is Softening
4. Transparency #3 - Advantages of chemical precipitation
5. Transparency #4 - Disadvantages of chemical precipitation softening
6. Transparency #5 - Review of Terminology

Instructional Approach:

Discussion

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operators, Texas Water Utilities Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Introduction.

INSTRUCTOR GUIDE

for

Training Module II2T-WS

Module No:	Topic:
II2TWS	Principles of Chemical Precipitation Softening

Instructor Notes:	Instructor Outline:
1. Present Transparency #1	1. Discuss What Hardness Is a. Chemical Components of Hardness b. Types of Hardness 1) Carbonate 2) Non carbonate c. Typical Hardnesses in the U.S. d. Typical Hardnesses in Iowa.
2. Present Transparency #2	2. Discuss What Softening Is. a. Removal of Hardness b. Types of Softening 1. Chemical 2. Ion exchange
3. Present Transparency #3 and #4	3. Why Soften a. Advantages 1. Consume less soap and detergent. 2. Increase the life of clothing and other articles being cleaned. 3. Increase the life of pipes and fixtures, heating systems, and boiler shells and tubes for depositing water. 4. Certain industrial processes require it. 5. Some indications that hard water may be the cause of certain cardiovascular diseases. 6. Remove radioactive nuclides. b. Disadvantages 1. With improper control, softened water may be more corrosive or scaling than the raw water. 2. Chemical precipitation softening produces a significant volume of sludge which has to be disposed of.
4. Present Transparency #5 Ask the class to provide the instructor with the correct definition for each term and write it on the transparency.	4. 1. Hardness - The concentration of Calcium, Magnesium and other divalent cations found in water. 2. Carbonate Hardness - That portion of hardness that is in combination with biocarbonate.

Module No:	Topic:
II2TWS	Principles of Chemical Precipitation Softening

Instructor Notes:	Instructor Outline:

3. Non Carbonate Hardness - That portion of hardness that is in combination with sulfates, chlorides, nitrates and other anions.

4. Softening - The removal of hardness ions from the water.

5. Chemical Softening - The removal of hardness ions by precipitation with lime and soda ash.

6. Ion Exchange Softening - The removal of hardness ions by exchanging them with sodium ions.

Module No:	Module Title:
	Basic Chemical Precipitation Softening
II2TWS	Submodule Title:
Approx. Time:	Topic:
2 hours	Principles of Chemical Precipitation Softening

Objectives: Upon completion of this topic, the participant will be able to:
1. Write the chemical reactions for chemical precipitation softening.
2. Write the chemical reaction for recarbonation.

Instructional Aids:

1. Handout-Principles of Chemical Precipitation Softening.
2. Transparency #6 & 7 - Softening Reactions
3. Transparency #8-Recarbonation Reactions

Instructional Approach:

Discussion and Class Problem

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operators, Texas Water Utilities Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Principles of Chemical Precipitation Softening.
2. Complete Problem #1 on chemical reactions.

Module No: II2TWS	Topic: Principles of Chemical Precipitation Softening

Instructor Notes:	Instructor Outline:
1. Present Transparency #6	1. Discuss the softening reactions for carbonate hardness.
2. Present Transparency #7	2. Discuss the softening reactions for noncarbonate hardness.
3. Present Transparency #8	3. Discuss the recarbonation reactions.
4. Present Class Problem #1 Work Part A with class participation. Have class work Part B on their own and help those with problems.	4. Part A 1. 1 mole 2. (250 mg/l)/(162 mg/m mole)(1 mole) (74 mg/m mole) = 114 mg/l $Ca(OH)_2$ 3. 500-250 = 250 mg/l Part B 1. 1 mole of lime and 1 mole of soda ash 2. For Calcium 114 mg/l $Ca(OH)_2$ For magnesium (250 mg/l)/(120 mg/m mole)(1 mole) (74 mg/m mole) = 154 mg/l $Ca(OH)_2$ (250 mg/l)/(120 mg/m mole)(1 mole) (106 mg/ m mole) = 221 mg/l Na_2CO_3 3. $900-250-\left(\frac{(250)(24)}{120}\right)+\left(\frac{(221)(46)}{106}\right)$ $CaCO_3$ mg Na 900-250 - 50 + 96 = 696 mg/l

Module No:	Module Title:
II2TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	
1 hour	Topic: Chemical Precipitation Softening Processes

Objectives: Upon completion of this topic, the participant will be able to:
1. Identify and describe two stage lime softening.
2. Identify and describe split treatment softening.
3. Identify and describe single stage lime followed by recarbonation softening.

Instructional Aids:
1. Handout - Chemical Precipitation Softening Processes
2. Transparency #9 - Two Stage Lime Softening
3. Transparency #10- Split Treatment Softening
4. Transparency #11- Single Stage Softening followed by recarbonation.

Instructional Approach:

Discussion and Class Problem

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operators, Texas Water Utilities Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:
1. The participant will read Handout-Chemical Precipitation Softening Processes.
2. The participant will complete Problem #2 on chemical processes.

Module No:	Topic:
II2TWS	Chemical Precipitation Softening Processes

Instructor Notes:	Instructor Outline:
1. Present Transparency #9	1. Disucss the various units in two stage softening and the purpose of each. Discuss the general types of waters that lend themselves to this type of process. Discuss advantages and disadvantages of this process. a. Each Stage Chemical reactions b. Chemical Costs c. Finished Water Quality d. Capital Costs
2. Present Transparency #10	2. Discuss the various units used in split treatment and the purpose of each. Discuss the general types of waters that lend themselves to this type of process. Compare advantages and disadvantages of this process to that of two stage softening. a. Carbon Dioxide b. Chemical Costs c. Finished Water Quality d. Capital Costs
3. Present Transparency #11	3. Discuss the various units used in single stage softening. Discuss the general types of waters that lend themselves to this type of process. Compare advantages and disadvantages of this process to that of the other two processes. a. Chemical Reactions b. Chemical Costs c. Finished Water Quality d. Capital Costs
4. Present Class Problem #2 Have class complete the problem on their own and then work problem with class participation.	4. 1. F 2. F 3. F 4. F 5. F Discuss each answer and use each question to stress the points of each process.

Module No:	Module Title:
T2TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	Topic:
1 hour	Types of Chemical Precipitation Softeners

Objectives: Upon completion of this topic, the participant will be able to:
1. Identify and describe straight line softening.
2. Identify and describe upflow solids contact unit softening.
3. Identify and describe "spiro-reactor" softening.

Instructional Aids:

1. Handout - Types of Chemical Precipitation Softeners.
2. Transparency #12- Straight line softener.
3. Transparency #13- Upflow solids contact softener.
4. Transparency #14 - "Spiractor" softener.

Instructional Approach:

Discussion

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operators, Texas Water Utilities Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Types of Chemical Precipitation Softeners

Module No:	Topic:
II2TWS	Types of Chemical Precipitation Softeners

Instructor Notes:	Instructor Outline:
1. Present Transparency #12	1. Discuss the configuration of units used in straight line softener. Explain each unit, the purpose of each and the way each should be generally operated. Explain advantages and disadvantages of straight line softeners. a. Process Loading & Finished Water b. Sludge Characteristics c. Capital Costs
2. Present Transparency #13	2. Discuss the internal parts of the upflow solids contact softener. Explain each part, the purpose of each and the way each should be generally operated. Explain advantages and disadvantages of upflow solids contact softener. a. Process Loading & Finished Water b. Sludge Characteristics c. Capital Costs
3. Present Transparency #14	3. Discuss the components of the "spiroactor" softener. Explain each component, the purpose of each and the way each should be generally operated. Explain advantages and disadvantages of "spiroactor" softener. a. Process Loading & Finished Water b. Sludge Characteristics c. Capital Costs

Module No:	Module Title:
I12TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	Topic:
3 hours	Basic Operation of Chemical Precipitation Softeners

Objectives: Upon completion of this topic, the participant will be able to:
1. State the control parameters for each type of chemical precipitation softening.

Instructional Aids:

1. Handout-Basic Operation of Chemical Precipitation Softeners.
2. Transparency #15 - Two Stage Softening
3. Transparency #16 - Split Treatment
4. Transparency #17 - Single Stage

Instructional Approach:

Discussion and class problem

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operators, Texas Water Utilities Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout-Basic Operation of Chemical Precipitation Softeners.
2. Complete Problem #3 on operation of chemical precipitation softeners.

Module No:	Topic:
II2TWS	Basic Operation of ~~Chemical~~ Precipitation Softeners

Instructor Notes:	Instructor Outline:
1. Present Transparency #15	1. Discuss the operation of a two stage softening plant. Include how each type of softener is affected and what reactions are taking place.
2. Present Transparency #16	2. Discuss the operation of a split treatment softening plant. Include how each type of softener is affected and what reactions are taking place.
3. Present Transparency #17	3. Discuss the operation of a single stage softening plant. Include how each type of softener is affected and what reactions are taking place.
4. Present Class Problem #3 and work with class participation.	4. a. Single stage b. Single stage c. Single stage d. Two stage e. Split treatment f. Two stage g. Split treatment-two stage h. Two stage i. Split treatment-two stage Work each problem showing the final water quality and operational parameters for each case.

Module No:	Module Title:
II2TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	Topic:
2 hours	Water Stabilization

Objectives: Upon completion of this topic, the participant will be able to:

1. Determine the proper pH for a given treated water to control scale and corrosion.

Instructional Aids:

1. Handout-Water Stabilization
2. Transparency #18 - Factors affecting Water Stabilization
3. Transparency #19 - Reizener Index
4. Transparency #20 - Saturation pH

Instructional Approach:

Discussion and Class Problem

References:

1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operators, Texas Water Utilities Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:

1. The participant will read Handout - Water Stabilization.
2. The participant will complete Problem #4 - Water Stabilization.

Module No:	Topic:
II2TWS	Water Stabilization

Instructor Notes:	Instructor Outline:
1. Present Transparency #18	1. Discuss the factors and their importance in water stabilization. Discuss by passing water to achieve a 80 mg/l total hardness finished water.
2. Present Transparency #19	2. Discuss the Reizener curve and equation. Point out the index is only a guide and not absolute. For cold water a S.I. of 6.0 is a good starting point.
3. Present Transparency #20	3. Discuss the use of the diagram for use in calculating pHs. Work problem at bottom of diagram.
4. Present Class Problem #4 Have class work problem on their own. Then work the problem with class participation.	4. Review the idea of bypassing to obtain the desired water. Then calculate the proper finished water pH. a) $\frac{80}{360} = 27\%$ b) Hardness = 360 x 27% = 80 mg/l as $CaCO_3$ Calcium = 180 x 27% = 49 mg/l as $CaCO_3$ Alkalinity = 300 mg/l as $CaCO_3$ Temperature = $60^{o}F$ pH = 7.3 Total Dissolved Solids = 1000 mg/l Note: TDS has little effect on pHs therefore, assume a value slightly higher than natural water. c) pHs = 9.30 + .2 + 2.07-1.31-2.49 = 7.77 pH = 2(7.77)-6.0 = 9.5

Module No:	Module Title:
II2TWS	Basic Chemical Precipitation Softening Submodule Title:
Approx. Time: 1/2 hour	Topic: Safety

Objectives: Upon completion of this topic, the participant will be able to:
1. State the potential hazards in operating a chemical precipitation softener.
2. State the proper corrective measures to minimize safety hazards.
3. State the proper actions required after an accident.

Instructional Aids:
1. Handout - Safety
2. Transparency #21 - Safety

Instructional Approach:
Discussion

References:
1. Manual of Instruction for Water Treatment Plant Operators, Health Education Service.
2. Manual of Water Utility Operators, Texas Water Utilities Association.
3. Water Supply & Treatment, National Lime Association.

Class Assignments:
1. The participant will read Handout - Safety

Module No:	Topic:
II2TWS	Safety

Instructor Notes:	Instructor Outline:
T. Present Transparency #21	I. Discuss safety in operating a chemical precipitation softening plant.

Module No:	Module Title:
II2TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	Topic:
3 hours	Laboratory Control

Objectives: Upon completion of this topic, the participant will be able to:
1. Select the proper analytical tests for operational control.
2. Explain the analytical tests for operational control.
3. Interpret the results of analytical tests used in operational control.

Instructional Aids:
1. Handout - Laboratory Control
2. Transparency #22 - Laboratory Control

Instructional Approach:

Discussion

References:

1. Standard Methods for the Examination of Water and Wastewater, 14th Ed.
2. Methods for Chemical Analysis of Water and Waste, EPA.

Class Assignments:

1. The participant will read Handout - Laboratory Control

Module No:	Topic:
II2TWS	Laboratory Control

Instructor Notes:	Instructor Outline:
1. Present Transparency #22	1. Discuss the various laboratory analysis and the need for each.

Module No:	Module Title:
II2TWS	Basic Chemical Precipitation Softening
	Submodule Title:
Approx. Time:	Topic:
1 hour	Evaluation

Objectives:

The participant should be able to answer correctly 25 of the 30 questions asked.

Instructional Aids:

None

Instructional Approach:

Examination

References:

None

Class Assignments:

None

Module No:	Topic:
II2TWS	Evaluation

Instructor Notes:	Instructor Outline:
1. Distribute exam. Each participant is to complete the exam independently and with no books or notes. Collect after 1 hour.	

TRANSPARENCIES #1 - #22

for

Training Module II2TWS

WHAT IS HARDNESS?

1. CHEMICAL COMPONENTS
   A) Ca^{++}
   B) Mg^{++}
   C) OTHER

2. TYPES OF HARDNESS
   A) CARBONATE

      $Ca(HCO_3)_2$ OR $Mg(HCO_3)_2$

   B) NON CARBONATE

      $CaSO_4$ OR $Mg(Cl)_2$

WHAT IS SOFTENING?

1. REMOVAL OF HARDNESS

2. TYPES
   A) CHEMICAL PRECIPITATION
   B) ION EXCHANGE

WHY SOFTEN?

1. ADVANTAGES
   - A) CONSUME LESS SOAP AND DETERGENT
   - B) INCREASE THE LIFE OF CLOTHING AND OTHER ARTICLES BEING CLEANED.
   - C) INCREASE THE LIFE OF PIPES AND FIXTURES, HEATING SYSTEMS, AND BOILER SHELLS AND TUBES FOR DEPOSITING WATER.
   - D) CERTAIN INDUSTRIAL PROCESSES REQUIRE IT.
   - E) SOME INDICATIONS THAT HARD WATER MAY BE THE CAUSE OF CERTAIN CARDIOVASCULAR DISEASES.
   - F) REMOVE RADIOACTIVE NUCLIDES.

WHY SOFTEN?

2. DISADVANTAGES

A) WITH IMPROPER CONTROL, SOFTENED WATER MAY BE MORE CORROSIVE OR SCALING THAN THE RAW WATER.

B) CHEMICAL PRECIPITATION SOFTENING PRODUCES A SIGNIFICANT VOLUME OF SLUDGE WHICH HAS TO BE DISPOSED OF.

REVIEW OF TERMINOLOGY

1. HARDNESS -

2. CARBONATE HARDNESS -

3. NONCARBONATE HARDNESS -

4. SOFTENING -

5. CHEMICAL SOFTENING -

6. ION EXCHANGE SOFTENING -

SOFTENING REACTIONS

1. FREE CARBON DIOXIDE

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$$

CARBON DIOXIDE — LIME — CALCIUM CARBONATE — WATER

2. CALCIUM CARBONATE HARDNESS

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2\,CaCO_3\downarrow + 2\,H_2O$$

CALCIUM CARBONATE — LIME — CALCIUM CARBONATE — WATER

3. MAGNESIUM CARBONATE HARDNESS

$$Mg(HCO_3)_2 + 2\,Ca(OH)_2 \longrightarrow CaCO_3\downarrow + Mg(OH)_2\downarrow + 2\,H_2O$$

SOFTENING REACTIONS

4. CALCIUM NONCARBONATE HARDNESS

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$$

CALCIUM SULFATE	SODA ASH	CALCIUM CARBONATE	SODIUM SULFATE

5. MAGNESIUM NONCARBONATE HARDNESS

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + Mg(OH)_2\downarrow + Na_2SO_4$$

MAGNESIUM SULFATE	SODA ASH	LIME	CALCIUM CARBONATE	MAGNESIUM HYDROXIDE	SODIUM SULFATE

RECARBONATION REACTIONS

1. Excess Hydroxide

$$2\ OH^- + H_2CO_3 \longrightarrow CO_3^= + 2\ H_2O$$

Hydroxide Ion — Carbonic Acid — Carbonate Ion — Water

2. Calcium Carbonate

$$2\ CaCO_3 + H_2CO_3 \longrightarrow 2\ Ca(HCO_3)_2$$

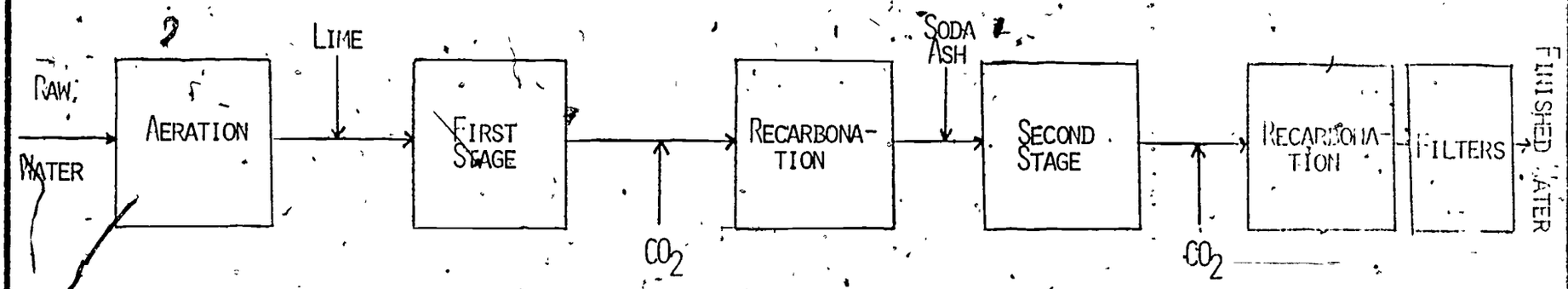
Calcium Carbonate — Carbonic Acid — Calcium Bicarbonate

3. Magnesium Hydroxide

$$Mg(OH)_2 + 2\ H_2CO_3 \longrightarrow Mg(HCO_3)_2 + 2\ H_2O$$

Magnesium Hydroxide — Carbonic Acid — Magnesium Bicarbonate — Water

TWO STAGE SOFTENING



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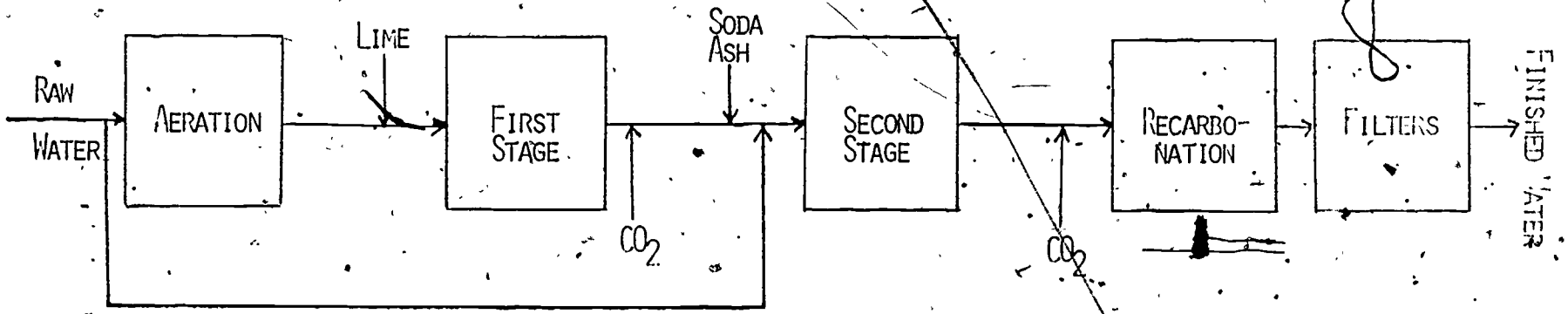
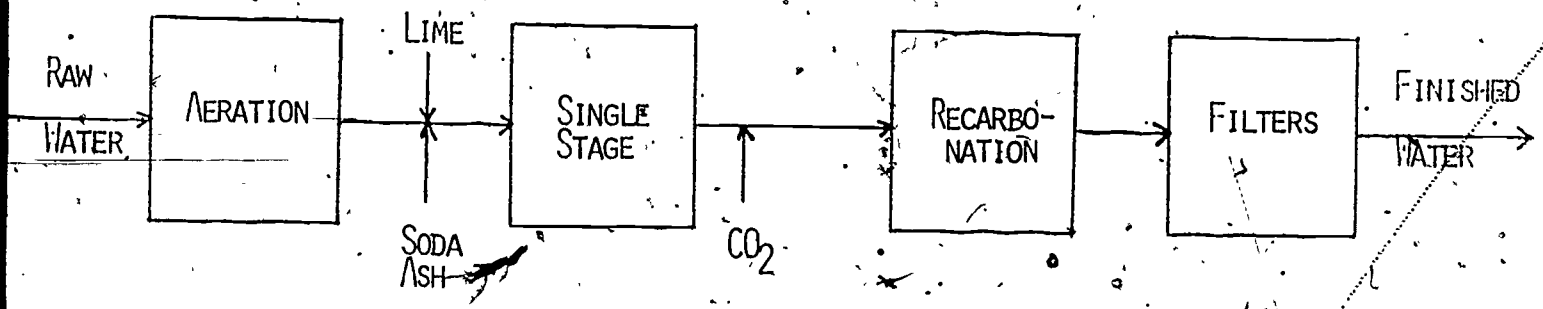
TRANSPARENCY #9

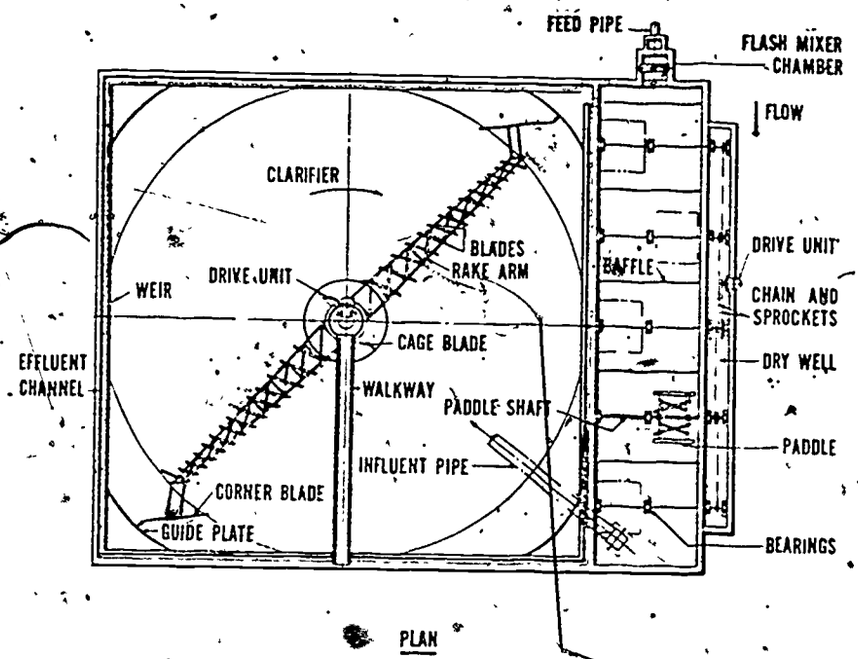
SPLIT TREATMENT SOFTENING



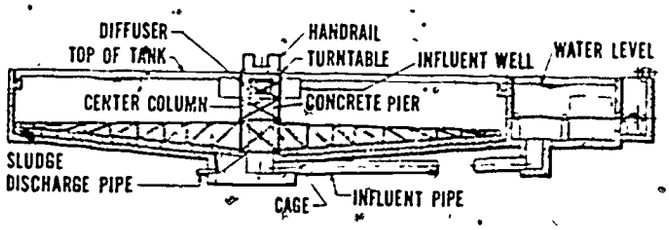
SINGLE STAGE SOFTENING



STRAIGHT LINE SETTLER



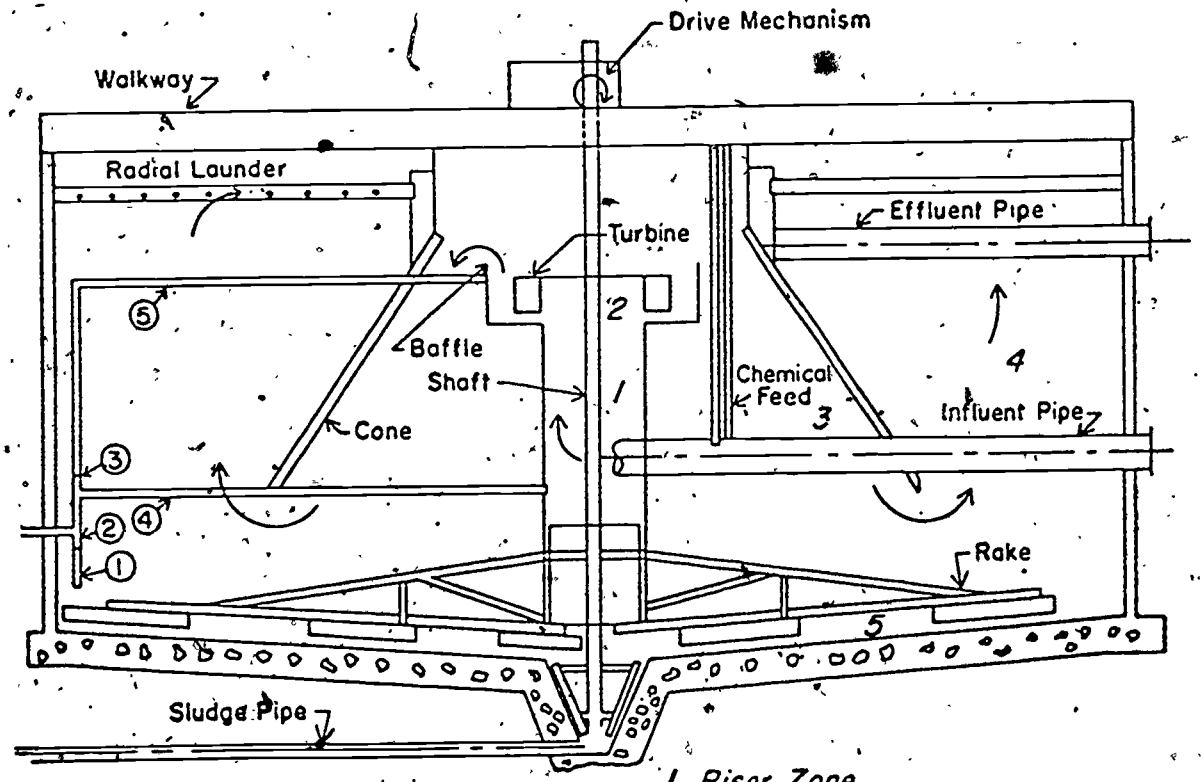
PLAN



SECTIONAL ELEVATION

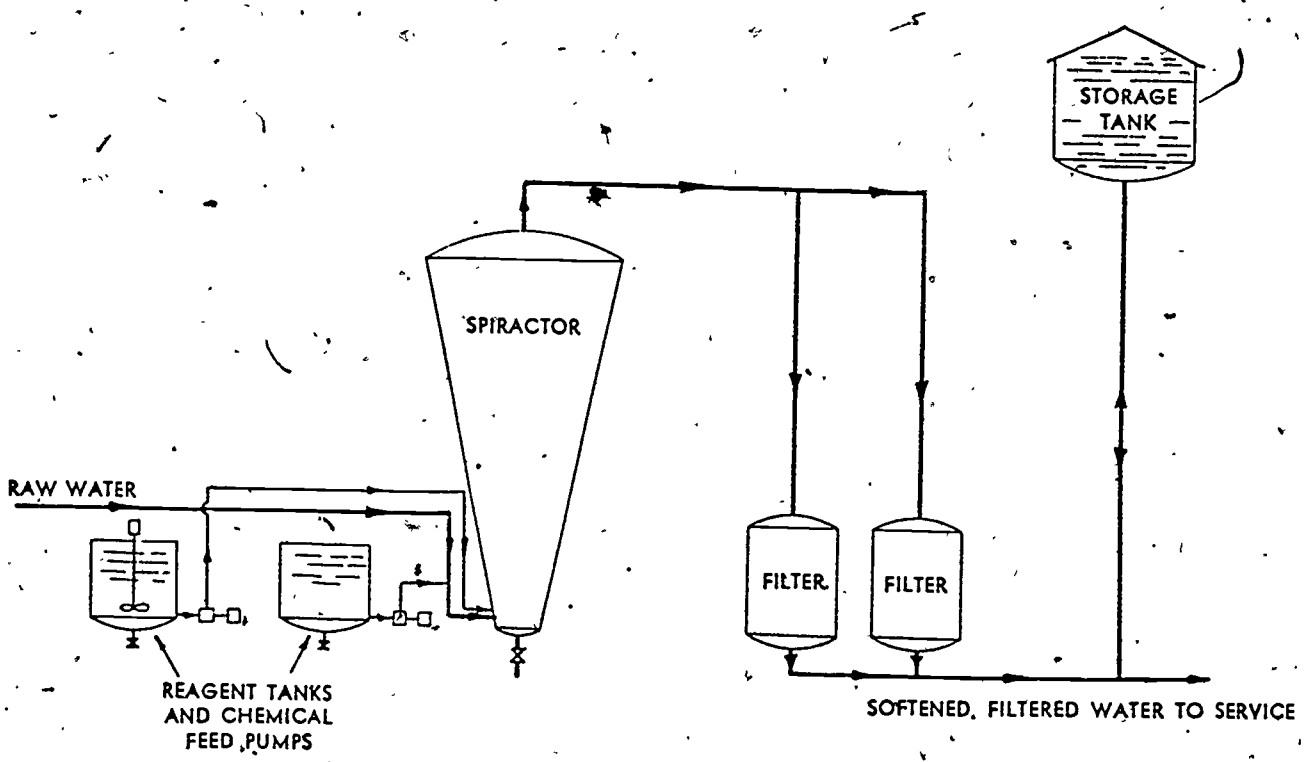
TRANSPARENCY 112THS - #12

UPFLOW SOLIDS CONTACT SOFTENER



1 Riser Zone
2 Primary Reaction Zone
3 Secondary Reaction Zone
4 Clarification Zone
5 Sludge Blanket and Thickening Zone

"SPIRACTOR" SOFTENER



TRANSPARENCY LIST S - #14

TWO STAGE SOFTENING

1. FIRST STAGE
   A) pH SHOULD BE ADJUSTED TO ABOVE 11.0 WITH LIME TO OBTAIN MAGNESIUM REMOVAL. THIS pH CAN BE REDUCED SOMEWHAT IF NOT TOTAL MAGNESIUM REMOVAL IS REQUIRED.
2. SECOND STAGE
   A) pH OF THE SECOND STAGE SHOULD BE APPROXIMATELY 10 TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   B) IF SODA ASH IS USED IT SHOULD BE ADDED JUST PRIOR TO THE SECOND STAGE TO HELP REDUCE THE pH.
   C) RECARBONATION WITH CARBON DIOXIDE IS USUALLY REQUIRED TO LOWER THE pH TO THE OPTIMUM LEVEL.
   D) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL pH IS DEPENDENT ON THE WATER, CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL pH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

SPLIT TREATMENT SOFTENING

1. FIRST STAGE
   A) pH SHOULD BE ADJUSTED TO ABOVE 11.0 WITH LIME TO OBTAIN MAGNESIUM REMOVAL. THIS pH CAN BE REDUCED SOMEWHAT TO OBTAIN THE DESIRED TOTAL MAGNESIUM REMOVAL.
2. SECOND STAGE
   A) pH OF THE SECOND STAGE SHOULD BE APPROXIMATELY 10 TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   B) IF SODA ASH IS USED IT SHOULD BE ADDED JUST PRIOR TO THE SECOND STAGE TO HELP REDUCE THE pH.
   C) GENERALLY THE CARBON DIOXIDE AND BICARBONATE IN THE SPLIT FLOW IS ADEQUATE TO LOWER THE pH IN THE SECOND STAGE TO OBTAIN OPTIMUM CALCIUM REMOVAL.
   D) IF pH DROPS BELOW 10.0 ADD ADDITIONAL LIME TO SEOND STAGE TO OBTAIN THE DESIRED CALCIUM REDUCTION.
   E) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL pH IS DEPENDENT ON THE WATER CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL pH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

SINGLE STAGE SOFTENING

1. SINGLE STAGE

   A) pH SHOULD BE ABOVE 10 TO OBTAIN ACCEPTABLE PERFORMANCE OF THE SOFTENER. IF MAGNESIUM REMOVAL IS DESIRED, THE pH SHOULD BE ABOVE 11.0. THE OPTIMUM OPERATION, THAT OPERATION RESULTING IN THE LEAST HARDNESS, WILL BE DIFFERENT FOR EACH PLANT, RESULTING IN SOME EXPERIMENTATION TO DETERMINE WHAT pH IS OPTIMAL.

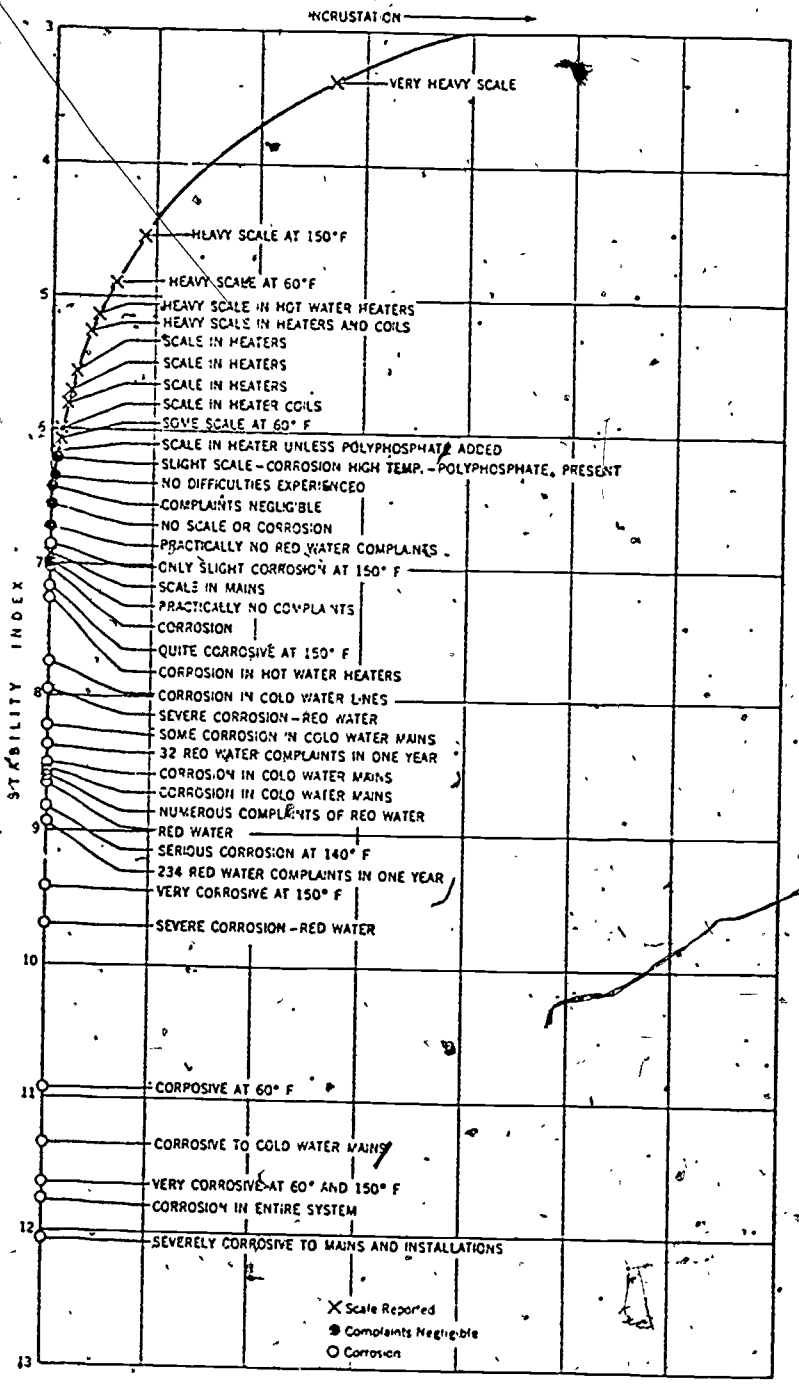
   B) ALL CHEMICAL FEEDS ARE ADDED JUST AT THE HEAD OF THE UNIT.

   C) RECARBONATION OF THE FINISHED WATER TO APPROXIMATELY 9.5 IS USUALLY REQUIRED TO PREVENT SCALE BUILDUP ON THE FILTERS. THIS FINAL pH IS DEPENDENT ON THE WATER, CHEMICAL AND PHYSICAL CHARACTERISTICS AND THEREFORE REQUIRES A CALCULATION OF THE FINAL pH FOR EACH PLANT TO ENSURE PROPERLY STABILIZED WATER.

FACTORS AFFECTING WATER STABILIZATION

1. Temperature
2. Calcium
3. Total Dissolved Solids
4. Alkalinity
5. pH

RYZNAR INDEX



S.I. = 2 pHs - pH

TRANSPARENCY NO. 20 "SATURATION PH" REMOVED PRIOR TO BEING SHIPPED TO EDRS FOR FILMING DUE TO COPYRIGHT RESTRICTIONS.

SAFETY

A. ELECTRICAL SAFETY

1. ALWAYS USE GROUNDED OR DOUBLE INSULATED ELECTRICAL TOOLS WHEN WORKING ON SOFTENERS OR CHEMICAL FEEDERS.

2. MAKE SURE ALL MOTORS AND ELECTRICAL CONTROLS ON SOFTENERS AND CHEMICAL FEEDERS ARE PROPERLY GROUNDED.

B. LIFTING CHEMICAL LIME AND SODA ASH BAGS

1. ALWAYS LIFE FROM THE KNEES TO PREVENT PERSONAL INJURY.

C. EYE PROTECTION

1. ALWAYS WEAR EYE PROTECTION WHEN HANDLING OR WORKING AROUND LIME OR SODA ASH FEEDERS.

2. ALWAYS WEAR PROTECTIVE COVERINGS ON HANDS AND ARMS WHEN HANDLING LIME AND SODA ASH.

3. IF LIME OR SODA ASH SHOULD COME IN CONTACT WITH EYE OR SKIN, FLUSH WITH A LARGE QUANTITY OF FRESH WATER AND CONTACT A PHYSICIAN IMMEDIATELY.

LABORATORY CONTROL

A. PHYSICAL
   1. TEMPERATURE
   2. TURBIDITY

B. CHEMICAL
   1. ALKALINITY
   2. TOTAL AND CALCIUM HARDNESS
   3. TOTAL DISSOLVED SOLIDS
   4. pH
   5. SOLIDS CONCENTRATION (UPFLOW UNITS ONLY)
   6. "CATALYST" ANALYSIS ("SPIRACTOR" ONLY)

CLASS PROBLEMS

for

Training Module II2TWS

CLASS PROBLEM #1

Part A

1. For a water containing calcium bicarbonate ($Ca(HCO_3)_2$), how many moles of lime will be needed to react with each mole of calcium?

2. If a water contained 250 mg/l of calcium bicarbonate, how much lime will be needed to soften the water?

3. If the water in Problem 2 had a total dissolved solids before softening of 500 mg/l, what will the total dissolved solids be after softening?

CLASS PROBLEM #1

Part B

1. For a water containing magnesium sulfate ($MgSO_4$), how many moles of lime and soda ash per mole ($MgSO_4$) will be required to soften the water?

2. If a water contained 250 mg/l of calcium bicarbonate and 250 mg/l of magnesium sulfate, how much lime and soda ash will be required to soften the water?

3. If the water in Problem 2 had a total dissolved solids before softening of 900 mg/l, what will the total dissolved solids be after softening?

CLASS PROBLEM #2

T or F 1. Single stage softening always obtains the softest water.

T or F 2. The first stage unit for two stage and split treatment is always operated for maximum magnesium removal.

T or F 3. Soda ash is always required for treatment in the second stage of a two stage or split treatment softening process.

T or F 4. Single stage softening is always the cheapest process for softening water.

T or F 5. Split treatment softening should always be used when softening surface water.

CLASS PROBLEM #3

1. If the desired finished water quality is a total hardness of 100 mg/l as $CaCO_3$, what process would be the most desirable for each of the following waters:

	Alkalinity	Calcium Hardness	Magnesium Hardness	Carbon Dioxide
a.	200	200	0	0
b.	200	100	100	20
c.	200	100	100	0
d.	350	200	150	0
e.	350	200	200	20
f.	100	250	250	0
g.	100	250	250	20
h.	100	100	350	0
i.	100	100	350	20

CLASS HANDOUT

for

Training Module II2TWS

Handout for TI2TWS - Basic Chemical Precipitation Softening

I. Introduction
   A. What is Hardness
      1. Chemical Components
         a) Ca
         b) Mg
         c) Other
      2. Types
         a) Carbonate
         b) Noncarbonate
      3. Typical hardness in U. S.
      4. Typical hardness in Iowa.
   B. What is Softening
      1. Removal of hardness
      2. Types of softening
         a) Chemical precipitation
         b) Ion exchange
   C. Why Soften
      1. Advantages
         a) Consume less soap and detergent
         b) Increase the life of clothing and other articles
         c) Increase the life of pipes and fixtures, heating systems, and boiler shells and tubes for depositing waters.
         d) Certain industrial processes require it.
         e) Some indications that hard water may be the cause of certain cardiovascular diseases.
         f) Remove radioactive nuclides.
      2. Disadvantages
         a) With improper control, softened water may be more corrosive or scaling than the raw water.
         b) Chemical precipitation softening produces a significant volume of sludge which has to be disposed of.

II. Principles of Chemical Precipitation Softening
   A. Softening Reactions
      1. Free Carbon Dioxide

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$$

Carbon Dioxide — Lime — Calcium Carbonate — Water

      2. Calcium Carbonate Hardness

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

Calcium Carbonate — Lime — Calcium Carbonate — Water

3. Magnesium Carbonate Hardness

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O$$

Magnesium Carbonate	Lime	Calcium Carbonate	Magnesium Hydroxide	Water

4. Calcium Noncarbonate Hardness

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$$

Calcium Sulfate	Soda Ash	Calcium Carbonate	Sodium Sulfate

Magnesium Noncarbonate Hardness

$$MgSO_4 + Na_2CO_3 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + Mg(OH)_2\downarrow + Na_2SO_4$$

Magnesium Sulfate	Soda Ash	Lime	Calcium Carbonate	Magnesium Hydroxide	Sodium Sulfate

B. Recarbonation Reactions

1. Excess Hydroxide

$$2\,OH^- + H_2CO_3 \longrightarrow CO_3^{=} + 2\,H_2O$$

Hydroxide Ion	Carbonic Acid	Carbonate Ion	Water

2. Calcium Carbonate

$$2\,CaCO_3 + H_2CO_3 \longrightarrow 2\,Ca(HCO_3)_2$$

Calcium Carbonate	Carbonic Acid	Calcium Bicarbonate

3. Magnesium Hydroxide

$$Mg(OH)_2 + 2\,H_2CO_3 \longrightarrow Mg(HCO_3)_2 + 2\,H_2O$$

III. Chemical Precipitation Softening Processes

A. Two Stage Softening (See Figure 1)

1. First Stage

a) Operate first stage at adequate pH for desired magnesium removal.

2. Second Stage

b) Add soda ash and/or carbon dioxide to reduce pH for optimum removal of calcium.

B. Split Treatment Softening (See Figure 2)
   1. First Stage
      a) Operate first stage at adequate pH for magnesium removal.
   2. Second Stage
      b) Bypass part of the raw water and/or add soda ash to reduce pH for optimum removal of calcium.

C. Single Stage Softening (See Figure 3)
   1. Single Stage
      a) Operate single stage for optimum total hardness removal.

IV. Types of Chemical Precipitation Softeners
   A. Straight line softener (See Figure 4)
   B. Upflow solids contact softener (See Figure 5)
   C. "Spiractor" softener (See Figure 6)

V. Basic Operation of Chemical Precipitation Softeners
   A. Two Stage Softening
      1. First Stage
         a) pH should be adjusted to above 11.0 with lime to obtain magnesium removal. This pH can be reduced somewhat if not total magnesium removal is required.
      2. Second Stage
         a) pH of the second stage should be approximately 10 to obtain optimum calcium removal.
         b) If soda ash is used it should be added just prior to the second stage to help reduce the pH.
         c) Recarbonation with carbon dioxide is usually required to lower the pH to the optimum level.
         d) Recarbonation of the finished water to approximately 9.5 is usually required to prevent scale buildup on the filters. This final pH is dependent on the water chemical and physical characteristics and therefore requires a calculation of the final pH for each plant to ensure properly stabilized water.

   B. Split Treatment Softening
      1. First Stage
         a) pH should be adjusted to above 11.0 with lime to obtain magnesium removal. This pH can be reduced somewhat to obtain the desired total magnesium removal.
      2. Second Stage
         a) pH of the second stage should be approximately 10 to obtain optimum calcium removal.
         b) If soda ash is used it should be added just prior to the second stage to help reduce the pH.
         c) Generally the carbon dioxide and bicarbonate in the split flow is adequate to lower the pH in the second stage to obtain optimum calcium removal.
         d) If pH drops below 10.0 add additional lime to second stage to obtain the desired calcium reduction.
         e) Recarbonation of the finished water to approximately 9.5 is usually required to prevent scale buildup on the filters. This final pH is dependent on the water chemical and physical characteristics and therefore requires a calculation of the final pH for each plant to ensure properly stabilized water.

B. Split Treatment Softening (See Figure 2)
   1. First Stage
      a) Operate first stage at adequate pH for magnesium removal.
   2. Second Stage
      b) Bypass part of the raw water and/or add soda ash to reduce pH for optimum removal of calcium.

C. Single Stage Softening (See Figure 3)
   1. Single Stage
      a) Operate single stage for optimum total hardness removal.

IV. Types of Chemical Precipitation Softeners
   A. Straight line softener (See Figure 4)
   B. Upflow solids contact softener (See Figure 5)
   C. "Spiroactor" softener (See Figure 6)

V. Basic Operation of Chemical Precipitation Softeners
   A. Two Stage Softening
      1. First Stage
         a) pH should be adjusted to above 11.0 with lime to obtain magnesium removal. This pH can be reduced somewhat if not total magnesium removal is required.
      2. Second Stage
         a) pH of the second stage should be approximately 10 to obtain optimum calcium removal.
         b) If soda ash is used it should be added just prior to the second stage to help reduce the pH.
         c) Recarbonation with carbon dioxide is usually required to lower the pH to the optimum level.
         d) Recarbonation of the finished water to approximately 9.5 is usually required to prevent scale buildup on the filters. This final pH is dependent on the water chemical and physical characteristics and therefore requires a calculation of the final pH for each plant to ensure properly stabilized water.

   B. Split Treatment Softening
      1. First Stage
         a) pH should be adjusted to above 11.0 with lime to obtain magnesium removal. This pH can be reduced somewhat to obtain the desired total magnesium removal.
      2. Second Stage
         a) pH of the second stage should be approximately 10 to obtain optimum calcium removal.
         b) If soda ash is used it should be added just prior to the second stage to help reduce the pH.
         c) Generally the carbon dioxide and bicarbonate in the split flow is adequate to lower the pH in the second stage to obtain optimum calcium removal.
         d) If pH drops below 10.0 add additional lime to second stage to obtain the desired calcium reduction.
         e) Recarbonation of the finished water to approximately 9.5 is usually required to prevent scale buildup on the filters. This final pH is dependent on the water chemical and physical characteristics and therefore requires a calculation of the final pH for each plant to ensure properly stabilized water.

C. Single Stage Softening
   1. Single Stage
      a) pH should be above 10 to obtain acceptable performance of the softener. If magnesium removal is desired, the pH should be above 11.0. The optimum operation, that operation resulting in the least hardness, will be different for each plant, resulting in some experimentation to determine what pH is optimal.
      b) All chemical feeds are added just at the head of the unit.
      c) Recarbonation of the finished water to approximately 9.5 is usually required to prevent scale buildup on the filters. This final pH is dependent on the water, chemical and physical characteristics and therefore requires a calculation of the final pH for each plant to ensure properly stabilized water.

VI. Water Stabilization
   A. Factors affecting water stabilization
      1. Temperature
      2. Calcium
      3. Total Dissolved Solids
      4. Alkalinity
      5. pH
   B. Reizener Index
      S.I. = 2 pHs-pH
   C. Saturation pH
      (See Figure 7)

VII. Safety
   A. Electrical Safety
      1. Always use grounded or double insulated electrical tools when working on softeners or chemical feeders.
      2. Make sure all motors and electrical controls on softeners and chemical feeders are properly grounded.
   B. Lifting chemical lime and soda ash bags
      1. Always lift from the knees to prevent personal injury.
   C. Eye protection
      1. Always wear eye protection when handling or working around lime or soda ash feeders.
      2. Always wear protective coverings on hands and arms when handling lime and soda ash.
      3. If lime or soda ash should come in contact with eye or skin, flush with a large quantity of fresh water and contact a physician immediately.

VIII. Laboratory Control
   A. Physical
      1. Temperature
      2. Turbidity
   B. Chemical
      1. Alkalinity
      2. Total and calcium hardness
      3. Total dissolved solids
      4. pH
      5. Solids concentration (Upflow units only)
      6. "Catalyst" analysis ("Spiractor" only)

TWO STAGE SOFTENING

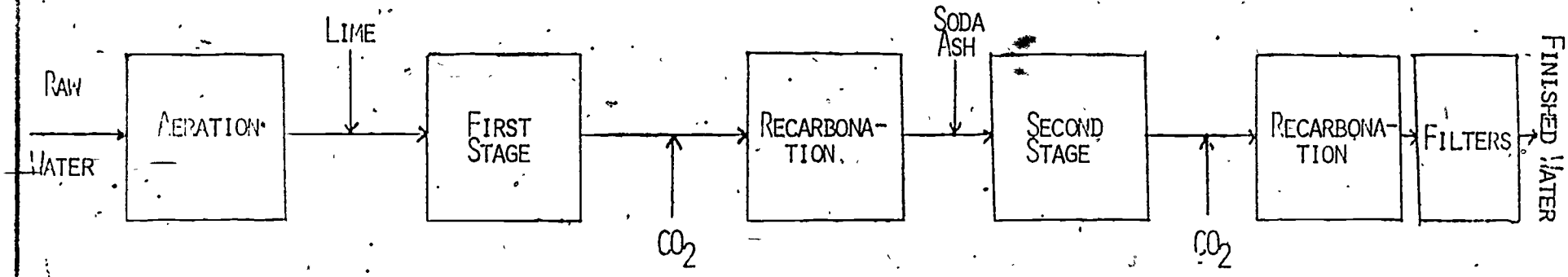


FIGURE II2TWS - #1

SPLIT TREATMENT SOFTENING

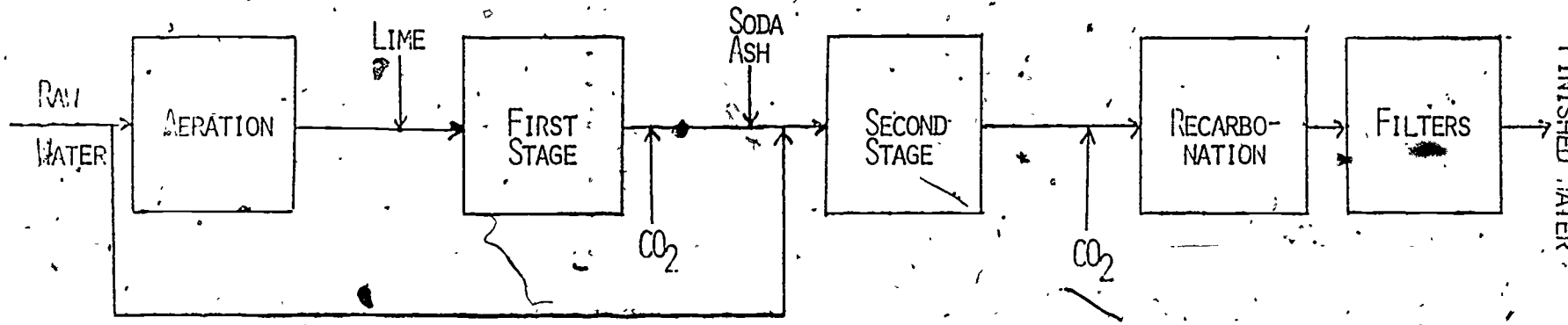


FIGURE II2TWS - #2

SINGLE STAGE SOFTENING

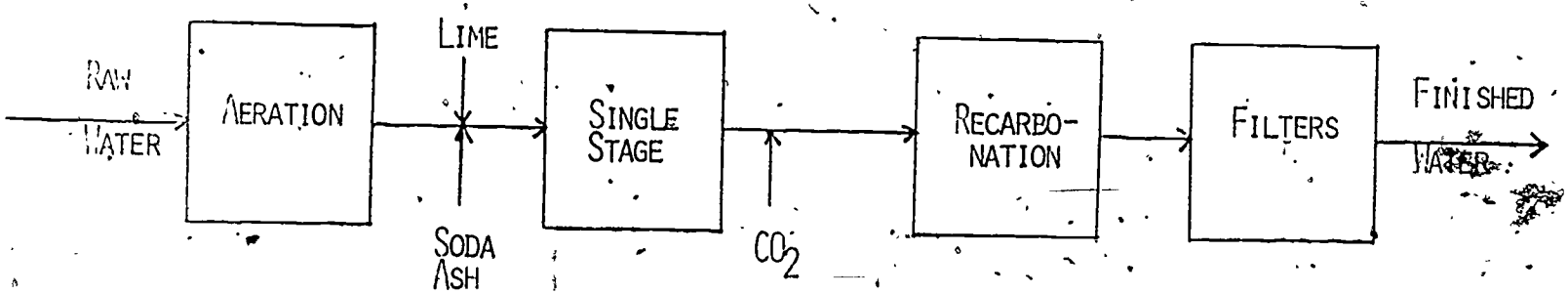


FIGURE II2TWS - #5

STRAIGHTLINE SOFTENING

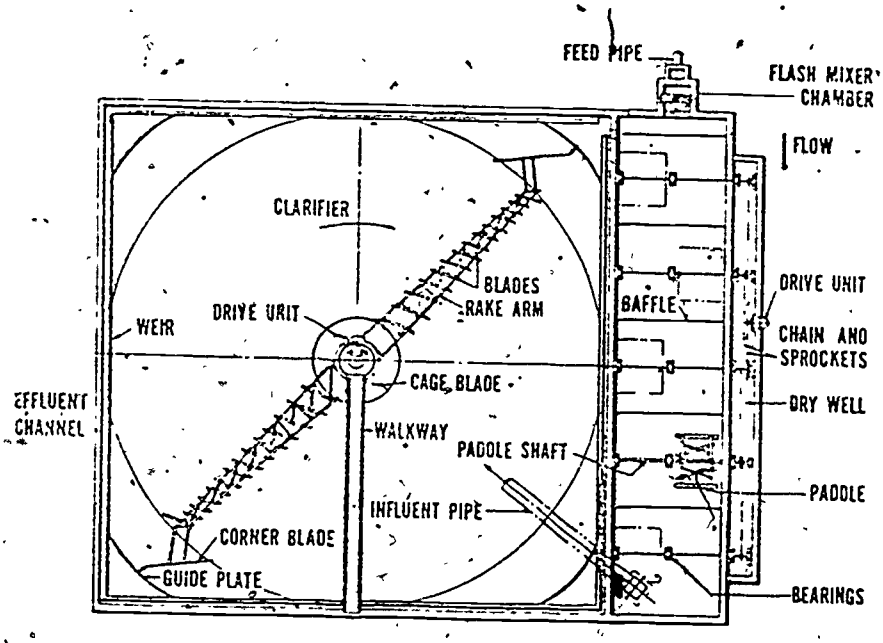
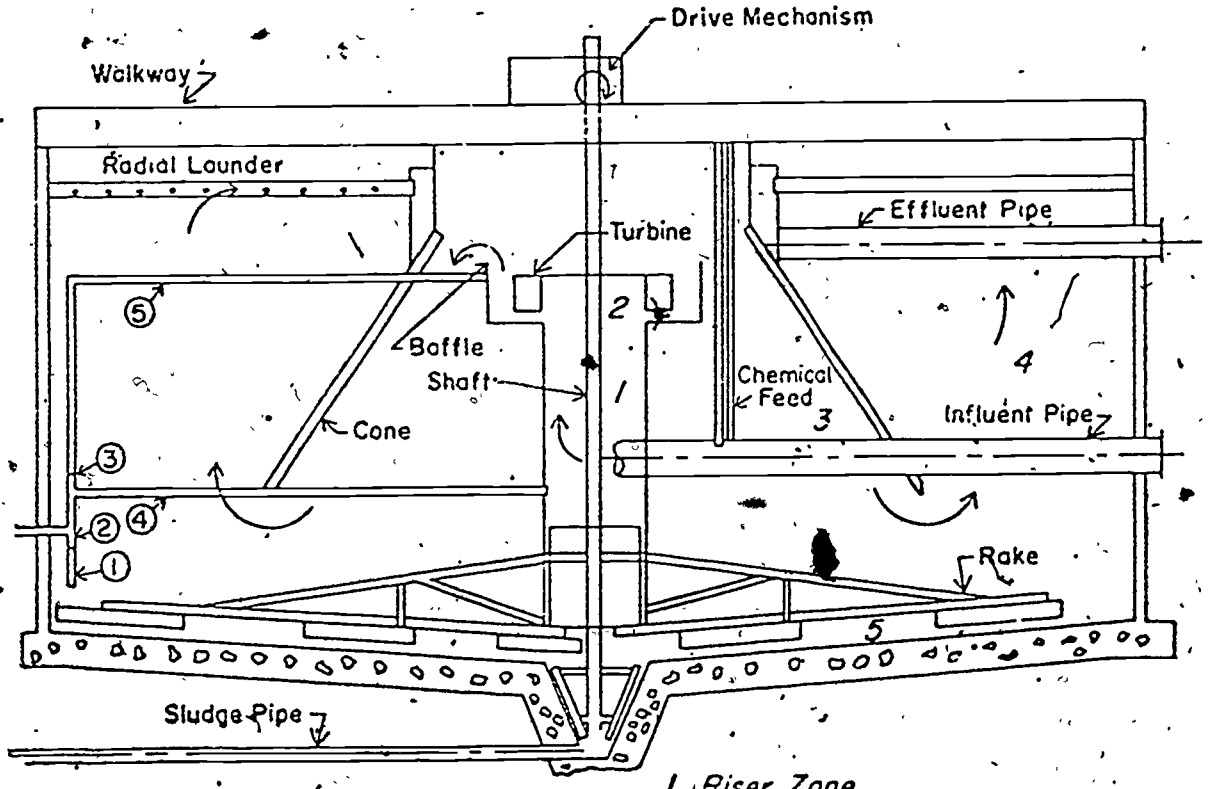


FIGURE 112T.S - 4

UPFLOW SOLIDS CONTACT SOFTENING



1 Riser Zone
2 Primary Reaction Zone
3 Secondary Reaction Zone
4 Clarification Zone
5 Sludge Blanket and Thickening Zone

FIGURE [illegible] - 5

"SPIRACTOR" SOFTENER

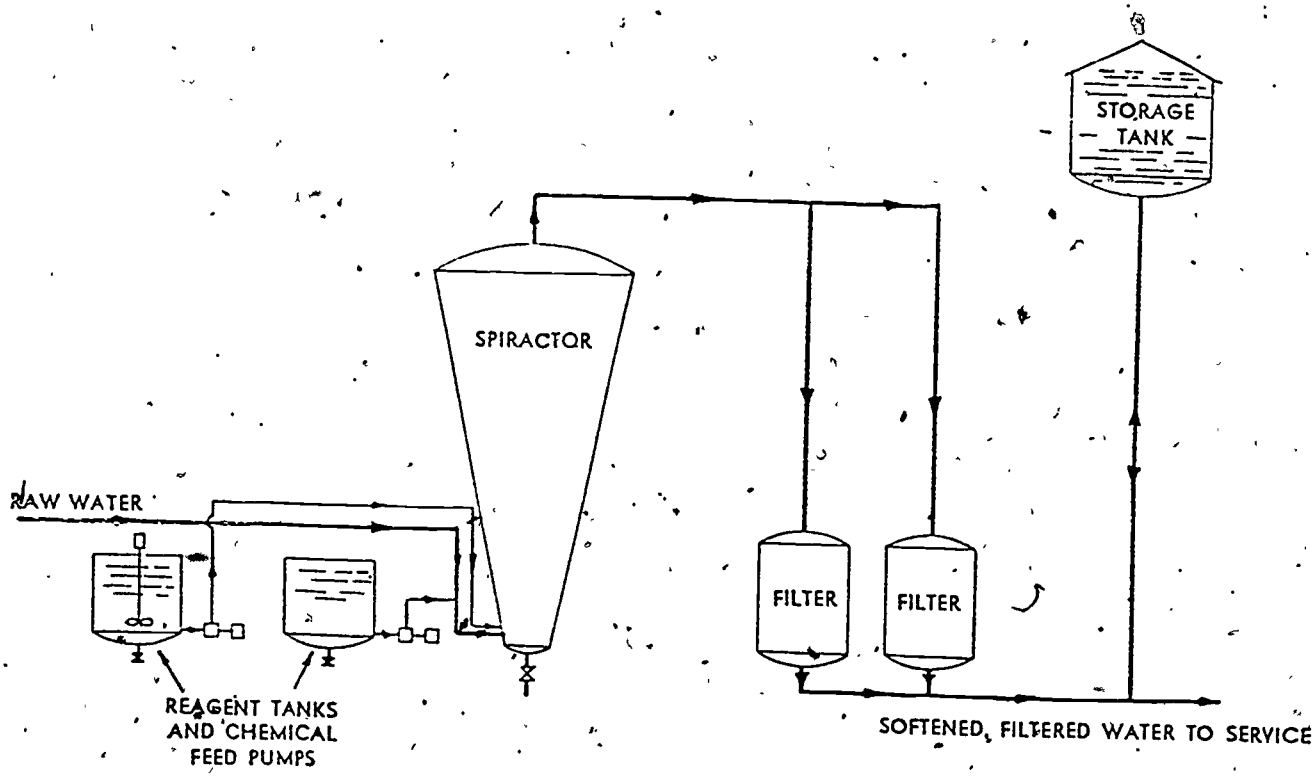


FIGURE H2T/S - 6

EXAMINATION

for

Training Module II2TWS

Examination for II2TWS - Basic Chemical Precipitation Softening

1. Hardness in most waters is caused by _____ and _____ divalent cation ions.

2. Hardness ions that are matched with bicarbonate anions are called _____ hardness.

3. Softening is defined as _____

_____

4. List three advantages of softening

a.
b.
c.

5. List two disadvantages of chemical precipitation softening

a.
b.

6. In chemical precipitation softening, calcium ions are removed as _____.

7. Soda ash is required for removal of _____ hardness.

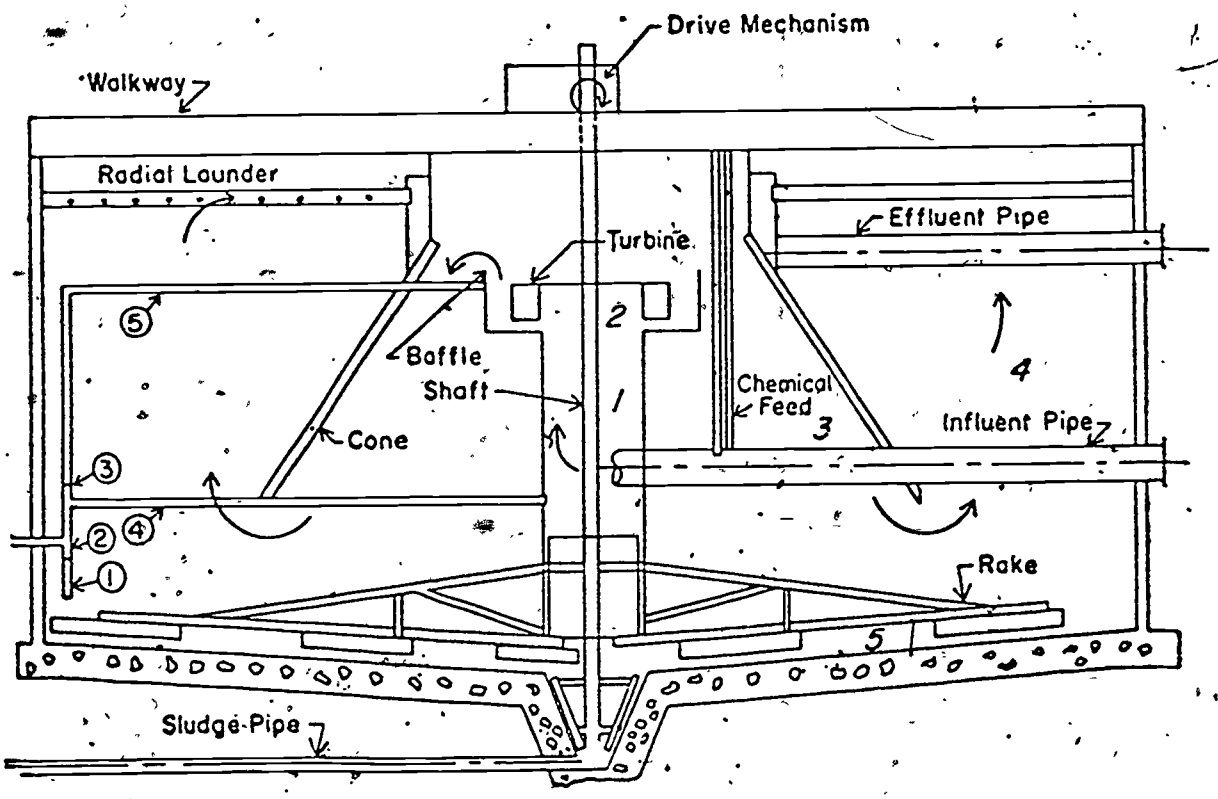
8. List the five factors affecting water stabilization.

a.
b.
c.
d.
e.

9. Magnesium is removed by adding _____ moles of lime for each mole or magnesium.

10. Match the appropriate number to the name for the various zones in an upflow solids contact unit.

Clarification Zone_____
Sludge Blank and Thickening Zone_____
Primary Reaction Zone_____
Secondary Reaction Zone_____
Riser Zone_____



TRUE OR FALSE. CIRCLE THE CORRECT ANSWER.

T or F 11. Carbon dioxide recarbonation is usually required to properly stabilize water after chemical softening.

T or F 12. A properly stabilized water always has a pH of 7.0.

T or F 13. When water contains $CaSO_4$ it is considered noncarbonate.

T or F 14. Radioactive particles are removed by chemical precipitation softening.

T or F 15. Total dissolved solids always generally decrease with chemical precipitation softening.

T or F 16. Split treatment should never be used for waters containing carbon dioxide.

T or F 17. Magnesium is removed from the water as magnesium carbonate ($MgCO_3$) in chemical precipitation softening.

T or F 18. A softener operating at a pH of 10.0 will have a significant amount of magnesium removal.

T or F 19. The advantage of the "Spiractor" is that it removes both noncarbonate and carbonate hardness.

T or F 20. Straight line softening is the easiest to operate but is also the easiest to upset.